(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 529 732 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **92202580.4**

(22) Date of filing: **25.08.92**

(51) Int. Cl.[5]: **H01S 3/103, H01S 3/133, H04B 10/14**

(30) Priority: **30.08.91 EP 91202204**

(43) Date of publication of application: **03.03.93 Bulletin 93/09**

(84) Designated Contracting States: **DE FR GB**

(71) Applicant: **N.V. Philips' Gloeilampenfabrieken**
Groenewoudseweg 1
NL-5621 BA Eindhoven(NL)

(72) Inventor: **Mols, Petrus Paulus Gerardus**
c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)
Inventor: **Hooijmans, Pieter Werner**
c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)
Inventor: **Tomesen, Markus Theodorus**
c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)

(74) Representative: **De Jongh, Cornelis Dominicus et al**
INTERNATIONAAL OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)

(54) **Turnable laser oscillator.**

(57) For tuning a laser (2) to a desired frequency, at least two frequency control electrodes are connected to an output of a control unit 8 in which preset values of the frequency control signals are stored for a variety of desired frequencies. In order to avoid undesired frequency jumps of the laser 2 occurring due to mode hopping, the control unit 8 provides a predetermined relation between the frequency control signals.

In an embodiment of the invention the preset values are corrected on the basis of a frequency difference between the laser 2 and a reference frequency measured by a frequency comparing element 6.

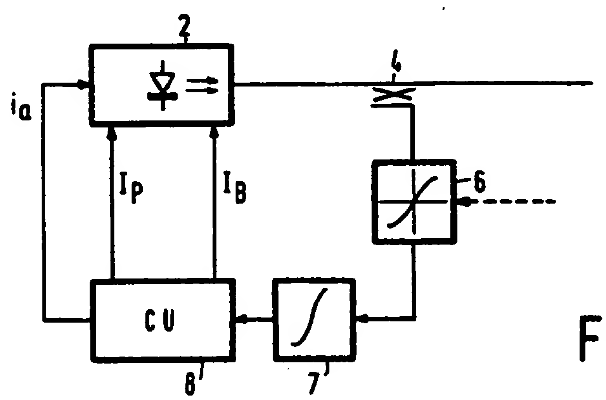


FIG.3

EP 0 529 732 A1

The invention relates to a tunable laser oscillator comprising a laser for producing an output signal and a control unit for applying a first tuning signal to a first control input of the laser, for tuning the laser to a desired frequency.

A laser oscillator of this type is known from United States Patent 4,914,666.

Such laser oscillators are used, for example, in transmitters or receivers for coherent optical transmission systems.

For transporting a baseband signal *via* a glass fibre in coherent optical transmission systems, the light signal coming from a transmitting laser can be amplitude, frequency or phase modulated by the baseband signal before it is fed to the glass fibre.

For demodulating the light signals at the receiver with the aid of current electronic components, it is necessary to convert the light signal which has a very high frequency (for example, 10^{14} Hz) to a much lower intermediate frequency of, for example 10^9 Hz. For this purpose, the received light signal is combined in the receiver with a local laser-generated light signal with the aid of a photodiode. This combination provides an intermediate frequency signal which has a frequency equal to the difference frequency between the frequency of the received light signal and that of the locally generated light signal.

For simultaneously transporting more than a single signal *via* a glass fibre, lasers which are tunable over a large frequency range (for example, 500 GHz) are used in both the transmitter and the receiver. As a result, more transmitters and receivers can communicate *via* the same glass fibre without causing interference to one another.

The frequency of the light signal generated by a tunable laser depends, for example, on the value of one or more electrical signals which are applied to control inputs of the laser.

In prior-art laser oscillator a laser is used which has two control inputs. The same tuning signal generated by the control unit is applied to these control inputs through two resistors. The relation between a desired frequency and the associated tuning signal is determined in the control unit. This relation may be determined by means of a single measurement of the frequency of the light generated by the laser as a function of the tuning signal. The control signal may be, for example, a current flowing through an active part of the laser, but may also be a control signal which determines, for example, the temperature or another ambient condition of the laser.

A problem is that during the tuning operation in prior-art laser oscillator the frequency of the light signal generated by the laser may change in a jumpy fashion while, in addition, this frequency jump presents hysteresis. This is to say that when the tuning signal is increased slowly, the frequency jump occurs at a value different from the one when the value of the tuning signal is reduced. This is undesired because the relation between the tuning signal and the wavelength of the light generated by the laser is no longer unambiguously fixed, because two different frequencies may belong to a single value of the tuning signal.

It is an object of the invention to provide a tunable laser oscillator of the type mentioned in the opening paragraph, in which the occurrence of frequency jumps of the laser during the tuning process is avoided.

For this purpose, the invention is characterized, in that the control unit is arranged for applying at least a further tuning signal to a further control input of the laser for tuning the laser to the desired frequency while a disproportional relation between the tuning signals is stored in the control unit.

The invention is based on the recognition that the frequency jumps are caused in that the laser changes to a different oscillation mode when the tuning signal has specific values. It has appeared that there is to be a certain disproportional relation between the two frequency control signals for avoiding these frequency jumps. By giving, in accordance with the inventive idea, the two control signals a disproportional relation, the occurrence of frequency jumps during the laser tuning may be avoided.

It is conceivable that for other types of laser oscillators a disproportional relation between two or more control electrodes is necessary for other reasons (for example, for minimizing the spectral line width). This problem may then also be solved by implementing the measures according to the inventive idea.

If the intermediate frequency of a receiver is, for example, 1 GHz, the tuning accuracy of both the laser in the transmitter and the laser in the receiver is to be better than 0.1% with a tuning range of 500 GHz. For safeguarding this tuning accuracy of the laser oscillator, frequency comparing means in the known laser oscillator generate a signal which is a measure for the frequency difference between the light signal generated by the laser and a reference frequency. In order to reduce a frequency difference, the difference signal is simply added to the tuning signal in the known laser oscillator. As a result, it continues to be possible for boundaries between ranges covering different modes of oscillation to be transgressed. In order to avoid this, an embodiment is characterized, in that the laser oscillator comprises frequency comparing means for supplying the control unit with a frequency difference signal which is a measure for a difference between the frequency of the laser output signal and a reference frequency, the control unit comprising adapting means for adapting at least one of the tuning signals to reduce the frequency difference.

By adapting one or more tuning signals in the event of a frequency difference between the light signal generated by the laser and a reference frequency, there may be guaranteed that when the tuning signal is adapted the afore-mentioned disproportional relation between the tuning signals is maintained, so that boundaries between ranges which denote different oscillation modes will not be transgressed.

Another embodiment of the invention is characterized, in that the adapting means comprise a combining element for combining to a tuning signal the frequency difference signal with a preset value of the relevant tuning signal stored in a memory.

By realising the adaptation of the tuning signals by way of combining the difference signal with preset values stored in the control unit, a control loop is obtained which reduces the frequency difference to substantially zero while at the same time the tuning signal is avoided transgressing boundaries between ranges which denote different oscillation modes.

A further embodiment of the invention is characterized, in that the adapting means comprise correction means for correcting the preset value of at least a tuning signal stored in the memory in response to the frequency difference signal.

This makes it possible yet to keep the initial frequency difference small when a desired frequency is tuned to in the case where the laser is subjected to an ageing process. Consequently, if more than one reference frequency is supplied, the chance of a faulty reference frequency being tuned to is reduced. The manner in which this preset value may be adapted will be derived hereinafter.

Assuming that the laser is controlled by N tuning signals, the frequency of the light generated by the laser may be written as:

$$f = f(I_1, I_2, \cdots, I_{N-1}, I_N) \qquad (1)$$

The desired disproportional relation between the different tuning signals, to be termed tuning curve hereinafter, may be defined on the basis of N-1 functions of one of the tuning signals:

$$\begin{aligned} I_2 &= g_2(I_1) \\ I_3 &= g_3(I_1) \\ &\cdots\cdots \\ I_{N-1} &= g_{N-1}(I_1) \\ I_N &= g_N(I_1) \end{aligned} \qquad (2)$$

If for a certain preset value j of the signals I_1 to I_N the control loop generates correction signals $\Delta I_1^m(j)$, the new preset value

$$I'_1, I'_2, \ldots, I'_{N-1}, I'_N$$

is to satisfy:

$$\begin{aligned} f(I'_1(j), I'_2(j), \cdots, I'_{N-1}(j), I'_N(j)) &= f(I_1(j)+\Delta I_1^m(j), \cdots, I_N+\Delta I_N^m(j)) \\ I'_2 &= g_2(I'_1) \\ I'_3 &= g_3(I'_1) \\ &\cdots \\ I_{N-1}' &= g_{N-1}(I'_1) \\ I'_N &= g_N(I'_1) \end{aligned} \qquad (3)$$

(3) forms the system of N comparisons with N unknowns, so that the new preset value may be derived from (3). Since the functions f and g will generally be non-linear, the solution to (3) is usually to be determined numerically.

A further embodiment of the invention is characterized, in that for a finite number of desired laser oscillator tuning frequencies associated preset values of the tuning signals as well as a proportionality constant belonging to each preset value, which constant is used for determining the correction value, are stored in the memory.

Adapting the preset value of the tuning signals with the aid of proportionality constants, which constants may be different for each preset value, provides adapted preset values in a simple manner. The proportionality constants may then be selected such that over the entire tuning range boundaries between ranges denoting different oscillation modes are not transgressed. Hereinafter there will be derived which values are to be selected for the various constants. For the frequency correction caused by the control loop, there may be written in linear approximation:

$$\Delta f=\left(\frac{\partial f}{\partial I_1}\right)_j \cdot\Delta I_1^m(j) + \left(\frac{\partial f}{\partial I_2}\right)_j \cdot\Delta I_2^m(j) + \cdots + \left(\frac{\partial f}{\partial I_N}\right)_j \cdot\Delta I_N^m(j) \qquad (4)$$

where $(\partial f/\partial I_x)_j$ is the local derivative of the frequency of the laser-generated light to the current I_x for a given preset value j of the signals I_1 to I_N.

A similar frequency change may also be realised by adapting the preset value while maintaining the relation according to (2). Then there may be written:

$$\Delta f=\left(\frac{df}{dI_1}\right)_i \cdot\Delta I_1(i) \qquad (5)$$

Herein i is one of the optional preset values of the signals I_1 to I_N. Equalization of (4) and (5) produces for the adaptation of the preset value ΔI_1:

$$\Delta I_1=\frac{\left(\frac{\partial f}{\partial I_1}\right)_j}{\left(\frac{df}{dI_1}\right)_i}\cdot(\Delta I_1^m)_j + \frac{\left(\frac{\partial f}{\partial I_2}\right)_j}{\left(\frac{df}{dI_1}\right)_i}\cdot(\Delta I_2^m)_j + \cdots + \frac{\left(\frac{\partial f}{\partial I_N}\right)_j}{\left(\frac{df}{dI_1}\right)_i}\cdot(\Delta I_N^m)_j = \qquad (6)$$

$$K_1(i,j)\cdot\Delta I_1^m(j) + K_2(i,j)\cdot\Delta I_2^m(j) + \cdots + K_N(i,j)\cdot\Delta I_N^m(j)$$

Herein, the following holds for df/dI_1:

$$\left(\frac{df}{dI_1}\right)_i = \left(\frac{\partial f}{\partial I_1}\right)_i + \left(\frac{\partial f}{\partial I_2}\right)_i\cdot\left(\frac{dg_2}{dI_1}\right)_i + \cdots + \left(\frac{\partial f}{\partial I_N}\right)_i\cdot\left(\frac{dg_N}{dI_1}\right)_i \qquad (7)$$

For the correction values of the other tuning signals I_2 to I_N there may simply be derived:

$$\Delta I_k(i) = \left(\frac{dg_k}{dI_1}\right)_i \cdot\Delta I_1(i) \qquad (8)$$

The invention will now be further explained with reference to the drawing Figures in which like elements are denoted by like reference characters. Herein:

Fig. 1 shows a cross-section of a Distributed Bragg laser,

Fig. 2 shows a graph in which the boundaries of different oscillation modes of a laser are plotted against two tuning signals and in which a tuning curve according to the state of the art and a tuning curve according to the invention are shown;

Fig. 3 shows a block diagram of a tunable laser oscillator according to the invention;

Fig. 4 shows a block diagram of an embodiment of the frequency discriminator 6 to be used in the tunable laser oscillator as shown in Fig. 3;

Fig. 5 shows a block diagram of the control unit 8 to be used in the tunable laser oscillator as shown in Fig. 3;

Fig. 6 shows a tuning curve of a DBR Laser in which the adaptation of a preset value according to a first embodiment of the invention is shown;

Fig. 7 shows a tuning curve of a DBR laser in which the adaptation of the preset value according to a second embodiment of the invention is shown; and

Fig. 8 shows the tuning curve as shown in Fig. 7 in which the correction of the preset value is illustrated if the adaptation method according to a second embodiment of the invention is recurrently used.

In tunable laser oscillators may be used, for example, Distributed Bragg Reflector (DBR) lasers as shown in Fig. 1. Such a laser comprises an amplifier section L, a transmission line section P and a (reflecting) Bragg section B.

A current I_a is applied to the amplifier section L, which current is to exceed a certain threshold to make optical amplification possible. Currents I_p and I_B are applied to the transmission line section P and the Bragg section B respectively. The current I_p in the transmission line section determines the breaking index thereof and thus the phase rotation of the transmission line section. The current I_B in the Bragg section influences the breaking index thereof and thus determines the phase of the light reflected by the Bragg section.

For laser oscillation with a desired frequency the sum of the phase rotations in the Bragg section and the transmission line section P is to be equal to $K \cdot 2 \cdot \pi$ ($K \in N$), while the auxiliary condition that the phase rotation in the Bragg section B is to be nearest to $\pi/2$ is to be satisfied. In the event of large deviations from this auxiliary condition, aforementioned frequency jumps may occur during the laser tuning. These frequency jumps are the result of the sudden change from K to a value for which the phase rotation in the Bragg section B is nearer to $\pi/2$.

By giving suitably selected values to the currents I_B and I_p, the two conditions may be satisfied, so that the undesired frequency jumps do not occur. However, the desired relation between I_B and I_p is generally not proportional so that when there is a proportional relation between I_B and I_p, as is the case in a laser oscillator according to the state of the art, there may nevertheless be undesired frequency jumps. It is conceivable for the frequency of such a laser to be adjusted by means of temperature in addition to being adjusted by means of afore-mentioned currents. For this purpose, a temperature control circuit is present which is controlled by a temperature control signal. Obviously, such a temperature control signal is to be considered a frequency control signal.

In Fig. 2 a characteristic of a DBR laser is represented in which the boundaries of the different oscillation modes are plotted against the tuning signals on the two control inputs. These boundaries are denoted by the letter B. In the hatched area the oscillation mode is not determined unambiguously but is equal to the oscillation mode when the boundary B is transgressed. Also the tuning curve which represents the relation between the two tuning signals is shown as it is generated by a state-of-the-art laser oscillator (curve 1). It is clearly noticeable that during the tuning operation this tuning curve several times (point X and point Y) transgresses the boundary between different oscillation modes, so that a frequency jump will occur. By making, in accordance with the inventive idea, the relation between the two tuning signals disproportional, it is possible to avoid the boundary between different oscillation modes being transgressed. Such a disproportional relation is shown in curve 2.

In the laser oscillator as shown in Fig. 3 two outputs of the control unit 8 carrying frequency signals which are the two currents I_p and I_B are connected to two control inputs of the laser 2. In addition, an output of the control unit 8 carrying output signal I_a is connected to a power control input of the laser 2. The output of the laser 2 is connected to the output of the laser oscillator by way of the coupling element 4. A second output of the coupling element 4 is connected to an input of a frequency discriminator 6. In specific embodiments of the frequency discriminator 6 a further light signal is fed to a second input of the frequency discriminator 6. The output of the frequency discriminator 6 is connected to the input of an integrator 7. The output of the integrator 7 is connected to an input of the control unit 8. The frequency discriminator 6 and the integrator 7 together form the frequency comparing means.

For enabling the laser 2 to operate, the control unit 8 applies a signal, in this case a current I_a to the amplifier section of the laser. The power produced by the laser can be set with the aid of the current I_a.

Currents I_p and I_B are applied to the transmission line section and the Bragg section respectively. These currents are also supplied by the control unit 8.

The frequency of the light generated by the laser strongly depends on the temperature of the laser. To avoid that the frequency of the laser-generated light strongly deviates from a desired value as a result of temperature fluctuations, the laser is accommodated on a Peltier cooling element whose temperature may

be accurately maintained at a constant level.

The light available at the output of the laser is led to the destination *via* the coupling element 4. This destination may be a glass fibre but also a photodiode in an optical heterodyne receiver. A small portion of the light generated by the laser 2 is led to the frequency discriminator 6 *via* the coupling element 4. This frequency discriminator 6 determines the frequency difference between the light generated by the laser and a reference frequency. The output signal of the frequency discriminator, the frequency difference signal, which is a measure for the frequency difference, is integrated in the integrator 7 and then fed to the control unit 8. The control unit 8 now generates tuning signals I_p and I_B, so that the frequency difference and hence the input signal of the integrator becomes zero while the desired relation between I_B and I_p according to the tuning curve is maintained.

The control unit may adapt the tuning signals in various ways. A first way is to apply the output signal of the integrator 7 to one of the control inputs of the laser 2 while the other tuning signal is derived from the first tuning signal with the aid of an auxiliary circuit.

Fig. 4 shows an embodiment of the frequency discriminator 6. The light coming from the coupling element 4 of Fig. 1, together with a further optical signal, is applied to a photodiode 10. The further optical signal may be, for example, a light signal received from a transmitter through a glass fibre. As a result of interference of the two light beams an electric signal having a frequency equal to the frequency difference between the two light signals will be present in the output signal of the photodiode 10. The output signal of the photodiode is applied to an amplifier which amplifies the electric signal to a desired value. The output signal of the amplifier is applied to the input of a frequency discriminator 14 which determines on the basis of its input signal a frequency difference signal which is a measure for the frequency difference between the two light beams.

The frequency discriminator 6 will often form part of an optical heterodyne receiver by which information modulated on the further optical signal is received and demodulated. If information about the frequency of the further optical signal is modulated on this further optical signal (for example, a channel number), this information may be used for verifying a correct tuning of the laser oscillator. If the further optical signal comprises a plurality of optical carriers which have different frequencies, the control unit may compare the channel number set by a user with the channel number of the currently received carrier and, when there is a difference between the two, the control unit may start looking for the desired channel with the aid of a look-up procedure.

The frequency discriminator may also comprise, as does the frequency discriminator in aforementioned United States Patent, a Fabry-Perot resonator.

In the control unit 8 as shown in Fig. 5 the frequency difference signal is applied to an input of an analog-to-digital converter 15 which comprises combining means in this case constituted by an adder 11 and an adder 12. The output of the analog-to-digital converter 15 is connected to an input of a microprocessor 10.

A first output of the microprocessor 10 is connected to an input of a digital-to-analog converter 16. The output of the digital-to-analog converter 16 forms an output of the control unit 8 which carries output signal I_a.

A second output of the microprocessor 10 is connected to an input of a digital-to-analog converter 13. The output of the digital-to-analog converter 13 is connected to a further input of the adder 11. The output of the adder 11 forms an output of the control unit 8 which carries output signal I_p.

A third output of the microprocessor 10 is connected to an input of a digital-to-analog converter 14. The output of the digital-to-analog converter 14 is connected to a further input of the adder 12. The output of the adder 12 forms an output of the control unit 8 which carries output signal I_B.

In the control unit 8 the tuning signals I_p and I_B are obtained by adding the output signal of the integrator 8 to each of the preset values of the tuning signals. The preset value is coarsely tuned to a desired frequency, whereas the output signal adapts the frequency of the laser, so that the frequency difference signal becomes zero. The combination of the adders 11 and 12, the laser 2 (Fig. 3), the frequency discriminator 6 (Fig. 3) and the integrator 7 (Fig. 3) forms an automatic frequency control loop. The preset values of the tuning signals are stored in the memory of the microprocessor 10. A certain number of preset values are often stored in the memory of the microprocessor 10 to enable the laser oscillator to be tuned to different frequencies.

In many cases the frequency difference which can be determined by the frequency discriminator has a maximum value. This means that the laser may only be tuned correctly on the basis of the reference frequency when the frequency difference is smaller than this maximum value. For example, as a result of the ageing process of the laser it is possible for the initial frequency difference to slowly increase when the laser oscillator is tuned to a certain frequency. To avoid this initial frequency difference even exceeding the

maximum frequency difference at a specific instant, the preset value is regularly adjusted on the basis of the output signal of the integrator, so that the initial frequency difference remains small when the laser oscillator is tuned. This adjustment may be effected in various ways which will be explained hereinafter.

Fig. 6 shows a desired relation 20 between I_p and I_B. Fig. 6 additionally shows some curves (22,23) at which the frequency of the light generated by the laser remains constant. It is now assumed that one of the preset values of the tuning currents stored in the memory of the microprocessor 10 is represented by point A. A frequency f_0 belongs to this preset value. If the reference frequency is equal to f_1, afore-mentioned frequency control loop will provide that the frequency of the laser becomes equal to f_1. This is effected by adding the values ΔI_p and ΔI_B to the preset values I_p and I_B respectively. Fig. 6 shows that the tuning signals adopt the values indicated by point B.

If an analytical expression is available for both the tuning curve 20 and the curve of constant frequency 23, the preset value may be determined by determining the intersection C_2 of the curves 20 and 23. Generally, this is to be effected with the aid of numerical methods because usually no analytical expression can be found for the intersection. Such numerical methods are described, for example, in the book entitled "Einführung in die Numerische Mathematik I" by Josef Stoer, Springer Verlag, ISBN 0-387-05750-1, chapter 5.

The calculation of the correction values may be simplified if the curve 23 is approximated by a curve having a slope equal to the local derivative $(\partial I_p/\partial I_b)_A$ of the curve 22 in the point A. This derivative may be determined, for example, by an initial calibration measurement of the laser. The preset value found in this manner of the tuning signals is denoted C_1 in Fig. 6. Fig. 6 likewise shows that after the correction of the preset value there is still a frequency difference, but this is much smaller than the original frequency difference. For that matter, C_1 is much nearer to the correct value C_2 of the point A.

With the values ΔI_p and ΔI_B measured after the previous correction, similar corrections may be constantly made, so that the value C_1 may randomly form a good approximation of the correct value C_2.

For further simplification of the correction of the preset value, the curve 20 may be approximated by means of a plurality of preset value points and their derivatives $(\partial I_p/\partial I_b)$. The correction of the preset value is then made in accordance with the previously derived relations (5) and (6) in the following manner:

$$\begin{gathered} I_p' = I_p + \Delta I_p = I_p + K_1(j,j)\cdot\Delta I_b^m + K_2(j,j)\cdot\Delta I_p^m \\ I_b' = I_b + \left(\frac{dI_b}{dI_p}\right)_j \cdot \Delta I_p \end{gathered} \qquad (9)$$

Fig. 7 gives a graphic representation of this way of correction. The new preset value C_1 is now determined by the intersection of the curves 21 and 24. In this method the preset value is always situated on curve 24. Although this curve slightly deviates from curve 21, this deviation appears not to cause any problems in practice.

Alternatively, it is possible to correct all the preset values stored in the memory of the microprocessor 10 on the basis of the measured currents ΔI_p and ΔI_B.For this correction the following holds according to (5) and (6):

$$\begin{gathered} I_p'(i) = I_p(i) + \Delta I_p(i) = I_p(i) + K_1(i,j)\cdot\Delta I_p^m(j) + K_2(i,j)\cdot\Delta I_p^m(j) \\ I_b'(i) = I_b(i) + \left(\frac{dI_b}{dI_p}\right)_i \cdot \Delta I_p(i) \end{gathered} \qquad (10)$$

The coefficients K(i,j) may be experimentally determined as follows. The laser is tuned along the tuning curve to the frequencies f_i. For each setting the derivatives $\partial f_i/\partial I_b$ and $\partial f_i/\partial I_p$ are determined. In addition, the derivative dI_p/dI_b of the tuning curve is determined for each frequency f_i. The constants K(i,j) may then be determined from these data with the aid of (5) and (6).

Fig. 8 gives a graphic representation of the recurrent correction of the preset value. This drawing Figure shows that with the first correction the preset value shifts from point A to point C. With the second correction the preset value shifts from point C to point E, whereas with the third correction the preset value

shifts from point E to point G. This markedly shows that when the preset value is recurrently adjusted, this preset value eventually obtains a value for which the frequency difference becomes zero.

Claims

1. Laser oscillator comprising a laser for producing an output signal and a control unit for applying a first tuning signal to a first control input of the laser, for tuning the laser to a desired frequency, characterized in that the control unit is arranged for applying at least a further tuning signal to a further control input of the laser for tuning the laser to the desired frequency while a disproportional relation between the tuning signals is stored in the control unit.

2. Laser oscillator as claimed in Claim 1, characterized in that the laser oscillator comprises frequency comparing means for supplying the control unit with a frequency difference signal which is a measure for a difference between the frequency of the laser output signal and a reference frequency, the control unit comprising adapting means for adapting at least one of the tuning signals to reduce the frequency difference.

3. Laser oscillator as claimed in Claim 2, characterized in that the adapting means comprise a combining element for combining to a tuning signal the frequency difference signal with a preset value of the relevant tuning signal stored in a memory.

4. Laser oscillator as claimed in Claim 3, characterized in that the adapting means comprise correction means for correcting the preset value of at least a tuning signal stored in the memory in response to the frequency difference signal.

5. Laser oscillator as claimed in Claim 4, characterized in that the correction means comprise adding means for adding to the preset value stored in the memory a correction value which is proportional to the frequency difference signal.

6. Laser oscillator as claimed in Claim 4 or 5, characterized in that for a finite number of desired laser oscillator tuning frequencies associated preset values of the tuning signals as well as a proportionality constant belonging to each preset value, which constant is used for determining the correction value, are stored in the memory.

7. Tunable laser oscillator as claimed in Claim 4, 5 or 6, characterized in that the correction means likewise comprise means for correcting preset values belonging to different tuning frequencies from the currently desired tuning frequency.

8. Laser oscillator as claimed in one of the Claims 2 to 8, characterized in that the frequency comparing means are further arranged for receiving a further optical signal, the frequency of the further optical signal being the reference frequency.

9. Laser oscillator as claimed in Claim 8, characterized in that the laser oscillator comprises means for receiving information modulated on the further light signal on the wavelength of the further light signal.

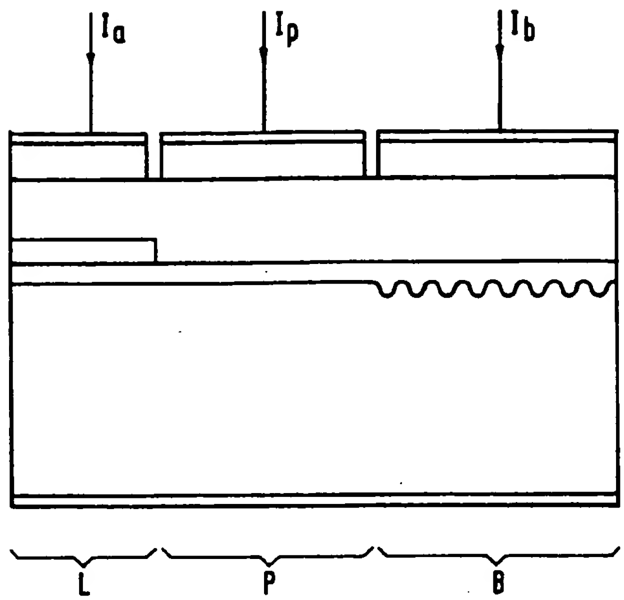


FIG.1

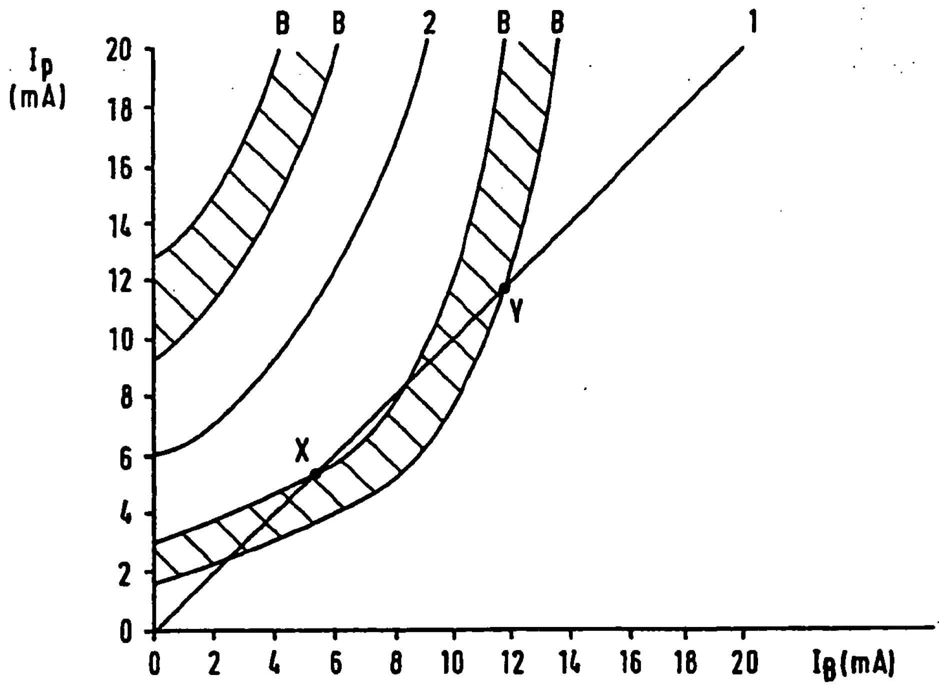


FIG.2

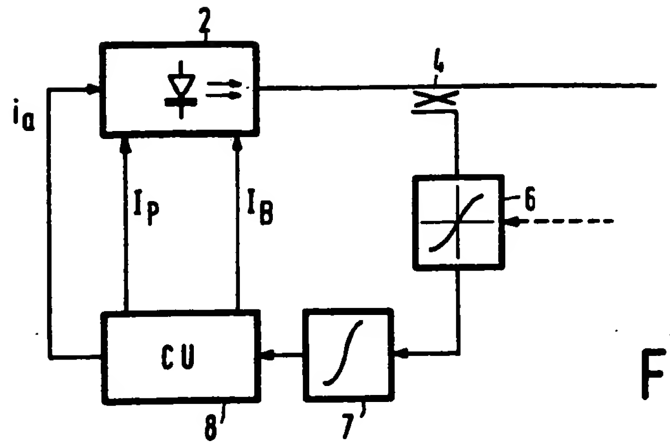


FIG.3

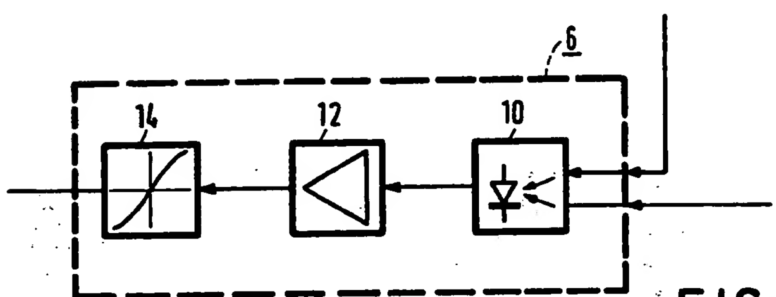


FIG.4

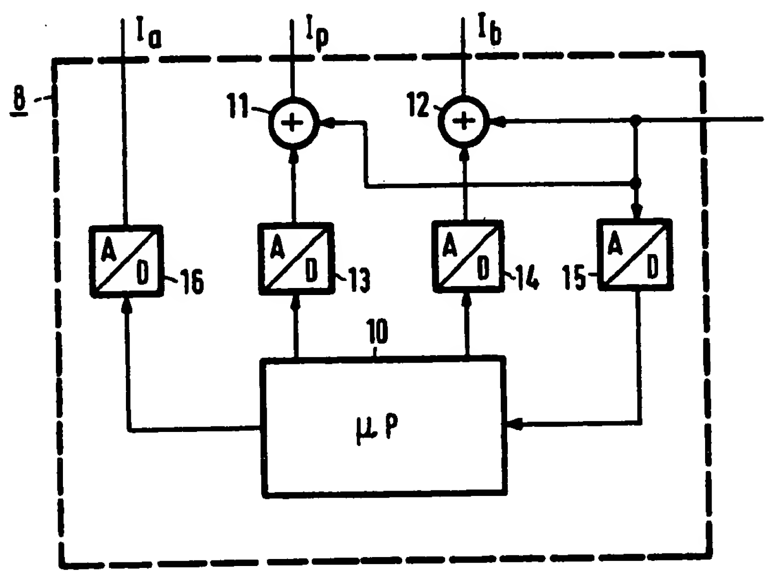
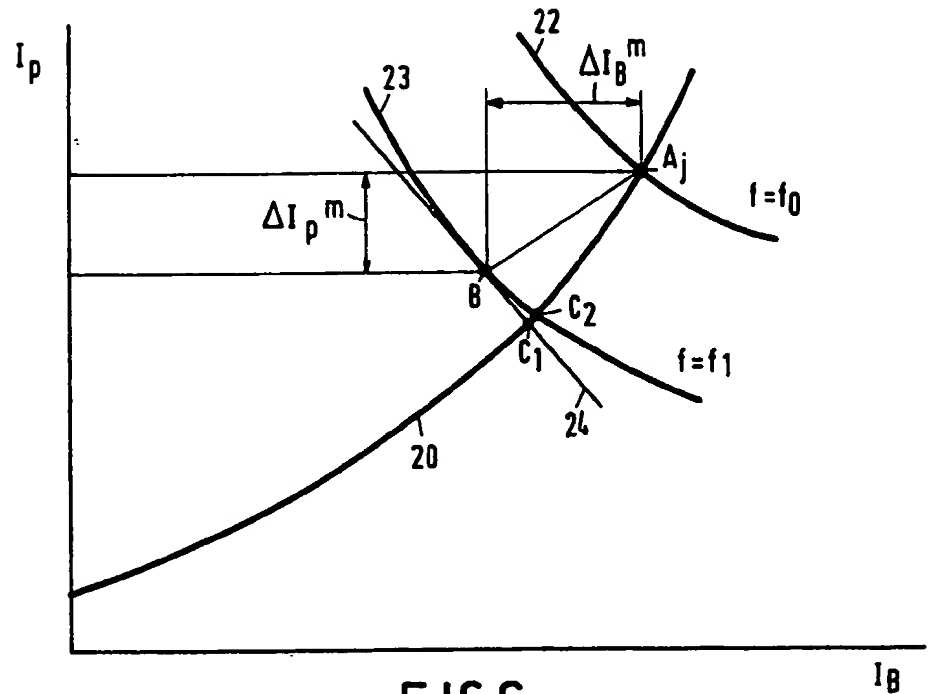
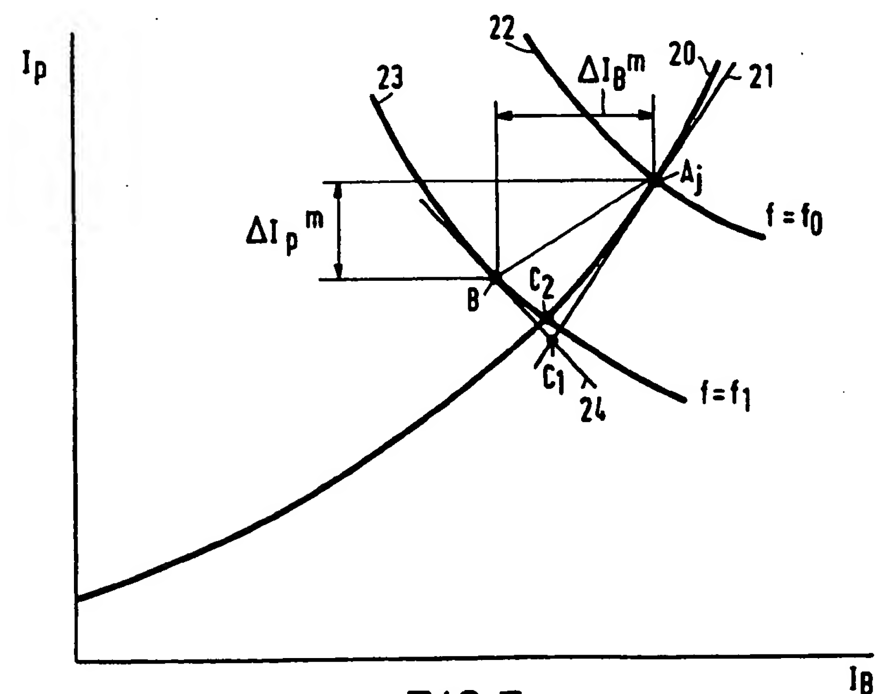


FIG.5



I_p
22
$\Delta I_B{}^m$
23
A_j
$f=f_0$
$\Delta I_p{}^m$
B
C_2
C_1
$f=f_1$
24
20
I_B

FIG.6



I_p
22
$\Delta I_B{}^m$
20
21
23
A_j
$f=f_0$
$\Delta I_p{}^m$
B
C_2
C_1
24
$f=f_1$
I_B

FIG.7

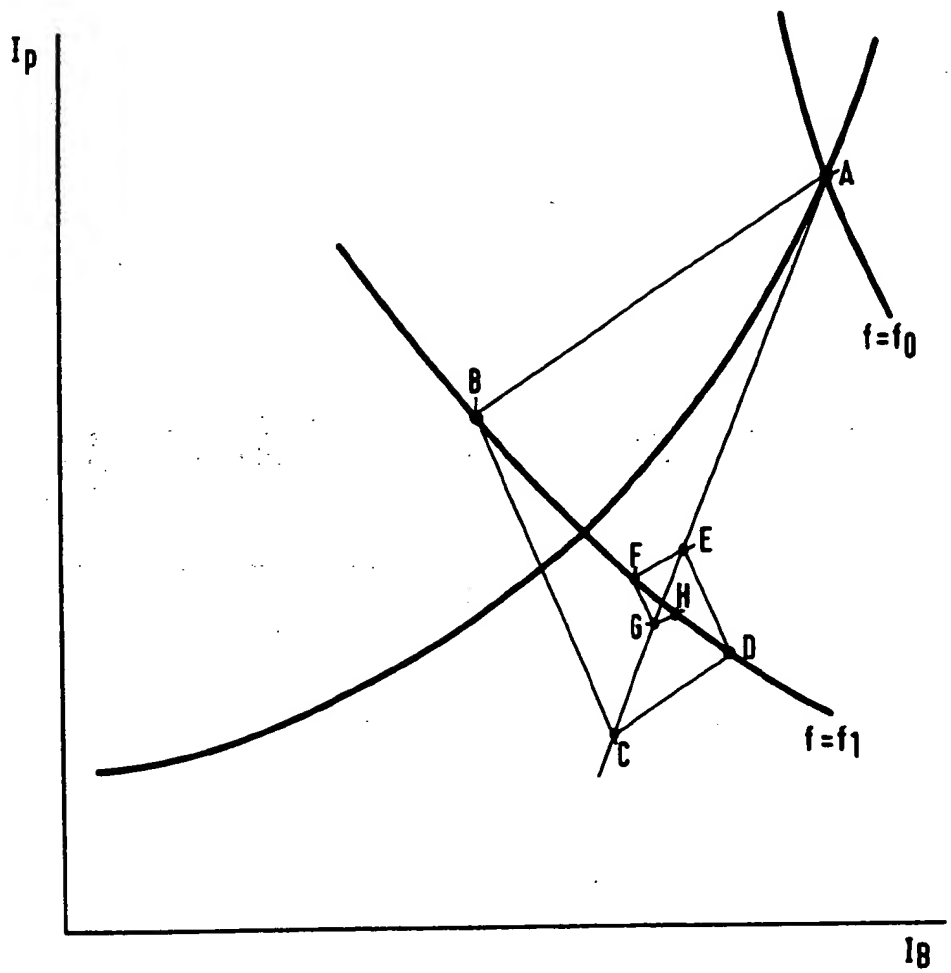


FIG.8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 20 2580

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,A	US-A-4 914 666 (BERNARD GLANCE) * column 1, line 1 - column 1, line 63 * * column 3, line 21 - column 6, line 63; figure 2 * ---	1-5	H01S3/103 H01S3/133 H04B10/14
A	US-A-4 916 705 (BERNARD GLANCE) * column 1, line 1 - column 2, line 12 * * column 3, line 39 - column 6, line 68; figure 2 * ---	1-5	
A	ELECTRONICS LETTERS. vol. 25, no. 17, 17 August 1989, STEVENAGE GB pages 1193 - 1195 B.GLANCE ET AL. 'Optical frequency synthesiser' * the whole document * ---	1-5	
A	IEEE GLOBAL TELECOMMUNCATIONS CONFERENCE & EXHIBITION, DECEMBER 2-5, 1990, SAN DIEGO, CALIFORNIA, US pages 766 - 767 B. GLANCE ET AL. 'One-THz digital random access high resolution optical frequency synthesizer providing cold-start operation from a frequency reference' * the whole document * -----	1-5	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H01S H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 NOVEMBER 1992	GNUGESSER H.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)